[i]REAL-TIME MANAGEMENT OF SEASONAL WETLAND DRAINAGE AS AN ALTERNATIVE FOR COMPLIANCE WITH SALINITY TMDL OBJECTIVES IN CALIFORNIA'S GRASSLANDS BASIN

Nigel W.T. Quinn[1]
W. Mark Hanna[2]

ABSTRACT

The California Regional Water Quality Control Board (CRWQCB) announced its salt and boron TMDL ("total maximum daily load") for the San Joaquin River Basin in April 2002. Wetland discharges of salt load to the San Joaquin River are being regulated for the first time as part of this TMDL together with agricultural and municipal sources of salt load. The Regional Board has offered an opportunity to entities within the San Joaquin River Basin to demonstrate a capability for real-time management of salt loads in order to qualify for a load excursion. The Grassland Water District (GWD), whose primary function is to supply surface water to private duck clubs and managed wetlands, is one of the entities regulated by the TMDL. To be eligible for the TMDL excursion, the GWD must cooperate with others to demonstrate the capability of managing salts released from the District to: (a) take advantage of periods of assimilative capacity in the San Joaquin River; and (b) limit salt loads discharged when assimilative capacity is impaired. Management of wetland sources of salt load requires the development of monitoring systems, integrative management strategies and coordination with other dischargers of salt loads within the San Joaquin Basin. This paper focuses on the steps being taken by the GWD to meet the challenges of participating in a real-time water quality management program. To meet the challenges within the GWD, a local and regional scale decision support system (DSS) is being developed to optimize wetland habitat requirements while tracking and managing salt loads to the San Joaquin River. The local scale DSS focuses on individual wetland management units where intensive management is practiced and intensive monitoring is being conducted. The regional scale DSS considers deliveries to and exports from the GWD Northern Division (NGWD).

INTRODUCTION

The Grassland Water District (GWD) is located in the San Joaquin Valley (Figure 1), and together with the adjacent State and Federal refuges, constitute the largest contiguous wetland in the State of California. The GWD provides water to more

[1]Group Leader, Hydroecological Engineering and Decision Support, Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720
2 Graduate Researcher, Dept. of Civil and Environmental Engineering, Boelter Hall, University of California, Los Angeles, Los Angeles, CA 90095

than 20,000 hectares of privately owned wetlands mostly used as over-wintering habitat for wildfowl on the Pacific Flyway. Seasonal wetlands in the GWD are flooded in the fall and drained in the spring to provide habitat for migratory waterfowl, shorebirds, and other wetland-dependent species. Due to alterations in natural hydrology, these wetlands are flooded with Central Valley Project water supplies delivered through GWD canals. In the spring, during the months of February-April, seasonal wetlands are drained to mimic the natural dry cycle of a seasonal wetland. Wetland drawdowns are timed to make seed and invertebrate resources available during peak waterfowl and shorebird migrations and to correspond with optimal germination conditions (primarily soil temperature) to grow desirable moist-soil plants. The seeds produced by these moist-soil plants are recognized as a critical waterfowl food source, providing essential nutrients and energy for wintering and migrating birds (Fredrickson and Taylor 1982).

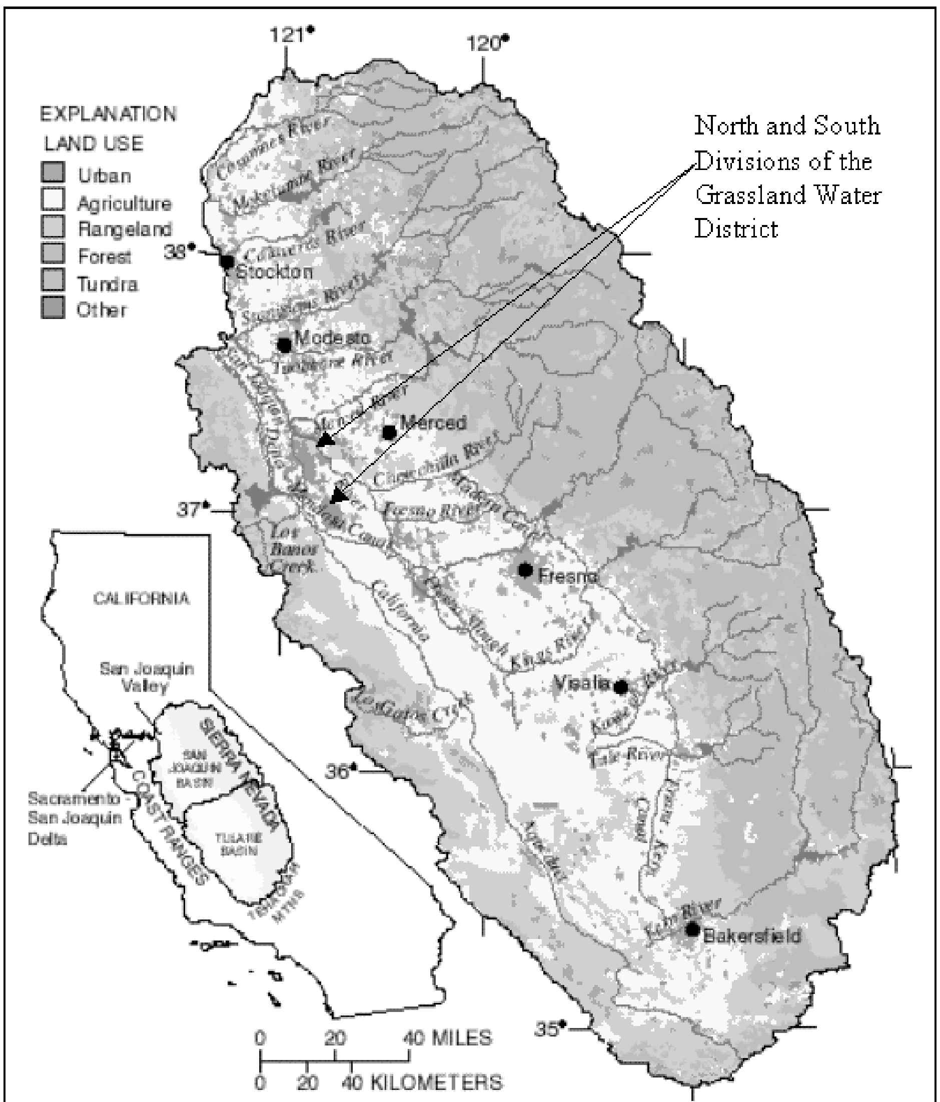

Figure 1. Location of Grassland Water District in San Joaquin River Basin.

SALINITY TMDL DEVELOPMENT

The Technical Salinity and Boron TMDL distributed for public comment in April 2002 (http://www.swrcb.ca.gov/~rwqcb5/programs/salt_boron/documents.html) describes the option of real-time water quality management as a means of meeting CRWQCB objectives as follows:

> "*...This option involves the identification or formation of an entity that would operate a real-time management program. This entity would be responsible for real-time forecasting and the allocation of loads among participating parties. The entity would also coordinate efforts to identify and implement salt and boron control efforts among participants with the goal of meeting the objectives set by the Board. Under this approach, the load limits allocated to this group of dischargers would vary depending on the assimilative capacity of the river...*
>
> *Real-time management would involve the coordinated release of saline discharges at times when there is assimilative capacity and retention of the wastewater at other times. This has the potential of increasing the allowable discharges, which in turn could result in lower costs for waste management...*
>
> *Salinity and boron levels in the LSJR could be managed at a basin scale if a real-time management program capable of tracking and scheduling discharges was put into place. The Regional Board could encourage such a program by indicating that the one entity that operates the real-time program will receive the allocation of all assimilative capacity over a base-line amount. The base-line amount would be the load the river can carry in drought years while still meeting objectives...*"

The CRWQCB has subsequently developed a draft implementation process for establishment of a real-time water quality management program.

DRAINAGE MANAGEMENT IN GRASSLAND WATER DISTRICT

The seasonal wetlands of the GWD are managed to meet habitat objectives by flooding in the fall and draining in the spring. Spring drainage is released into tributaries of the Lower San Joaquin River. These releases, in combination with agricultural drainage that flows through the GWD, contain varying amounts of total dissolved solids (TDS) and boron. These constituents have been identified as stressors to the aquatic ecosystem – stress levels are related to water quality objectives established for the San Joaquin River by state and federal agencies.

Wetland releases that contain high salt loads during the months of March and April coincide with agricultural pre-season irrigation to propagate plant seedlings. Saline water can inhibit germination and reduce crop yields. Better coordination of agricultural and wetland releases with reservoir releases of good quality snow-melt water on the east-side of the San Joaquin River Basin has been suggested as a means of improving San Joaquin River water quality for all beneficial uses (Quinn et al., 1997; Quinn and Karkoski, 1998). Quinn (1999) described the results of a demonstration project of real-time monitoring and management of agricultural drainage and east-side reservoir releases that forecasts the assimilative capacity for salinity on the San Joaquin River. Grober et al. (1995) suggested that wetland drainage from the GWD could be scheduled to coincide with peak assimilative capacity in the San Joaquin River to help improve downstream water quality. Increased water supply allocations under the Central Valley Project Improvement Act (CVPIA) have created opportunities to coordinate the release of seasonal wetland drainage with the assimilative capacity of the San Joaquin River to lower salt concentrations – benefiting downstream agricultural riparian water users and assisting in the reduction of an important stressor to fish populations.

Management of wetland drainage, through scheduling of releases to coincide with periods of San Joaquin River assimilative capacity, must be evaluated relative to potential biological impacts of changes to traditional wetland management practices. Peak assimilative capacity typically occurs between the months of January and March**.** This time period is often earlier than the traditional wetland draw-down period (March-April) (Figure 2). Hence, the response of moist-soil plants and of migratory waterfowl and shorebirds to an altered draw-down regime needs to be assessed..

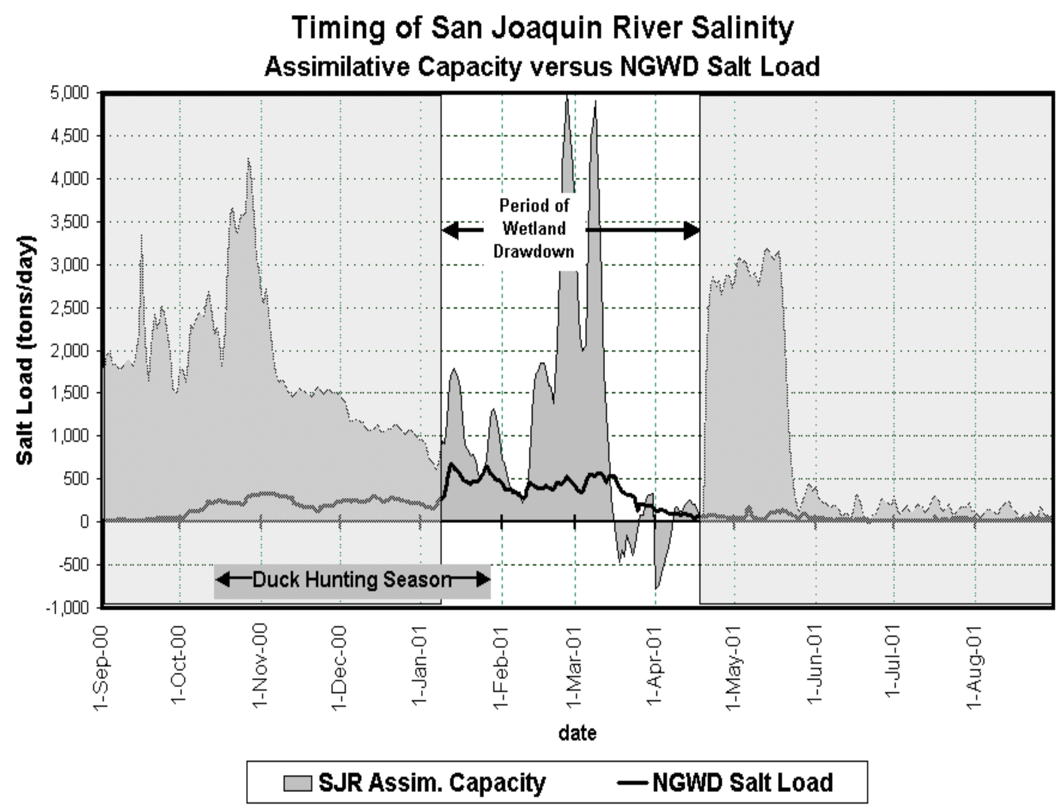

Figure 2. Salt loading from the North Grassland Water District to the San Joaquin River.

This assessment will identify potential impacts to seed germination rates, waterbird foraging rates, habitat availability, and species diversity and abundance. It is possible that early, experimental drawdown may make food sources available to wildlife without negatively affecting wetland vegetation community and plant species diversity - benefiting wildlife resources of the San Joaquin River Basin.

REAL-TIME FLOW AND WATER QUALITY MONITORING

Flow transducers and electrical conductivity sensors have been installed at control structures within the North Grassland Water District (NGWD). The GWD is divided into North and South Divisions of which the NGWD is the larger and contains the major drainage outlets to the San Joaquin River. The sensors take readings every 15 minutes to provide an accurate estimate of salt loading into and out of the NGWD. Flow and electrical conductivity data at each site is collected on a battery-powered datalogger that is attached to a phone telemetry system, allowing these data to be accessed 24 hours a day. Maps have been prepared locating water delivery and drainage turnouts in the NGWD drainage system. These maps document drainage hydrology within individual wetland basins. The location of the monitoring stations has been determined by GPS survey and plotted on GIS maps of the study area (Figure 3). These monitoring sites are strategically placed within wetland channels to allow computation of salt loads in real-time from the different drainage areas of the NGWD.

Real-time flow, electrical conductivity and temperature data from the NGWD is provided by e-mail and through a website (http://socrates.berkeley.edu/~ph299/NGWD/realtime.htm) as input to the real-time water quality model of the San Joaquin River operated by the SJRMP Water Quality Subcommittee http://wwwdpla.water.ca.gov/sjd/waterquality/realtime/index.html. The SJRMP Water Quality Subcommittee has been funded to enhance the existing network of real-time monitoring stations along the main-stem of the San Joaquin River and to improve the coordination of agricultural return flows and scheduled east-side fish flows (Quinn et al. 1997). Wetland discharge opportunities during the spring months, when the majority of saline discharges from seasonal wetlands occur, is evaluated weekly by the Project team, cooperatively with the watermaster and District biologist from the GWD.

HABITAT EVALUATION

A co-equal principal objective of the current water quality management project in the NGWD is to protect wetland habitat that may be affected by future potential changes in the flooding/drainage schedule. A biological and ecological monitoring component to the project is underway to document the effects of changing traditional flood-up and wetland drainage discharge patterns on wetland habitat (i.e., moist-soil plant production and water bird usage). Data developed in this monitoring program will help wetland managers design adaptive management approaches to optimize wetland habitat conditions while minimizing the negative effects of wetland drainage on the water quality in the San Joaquin River.

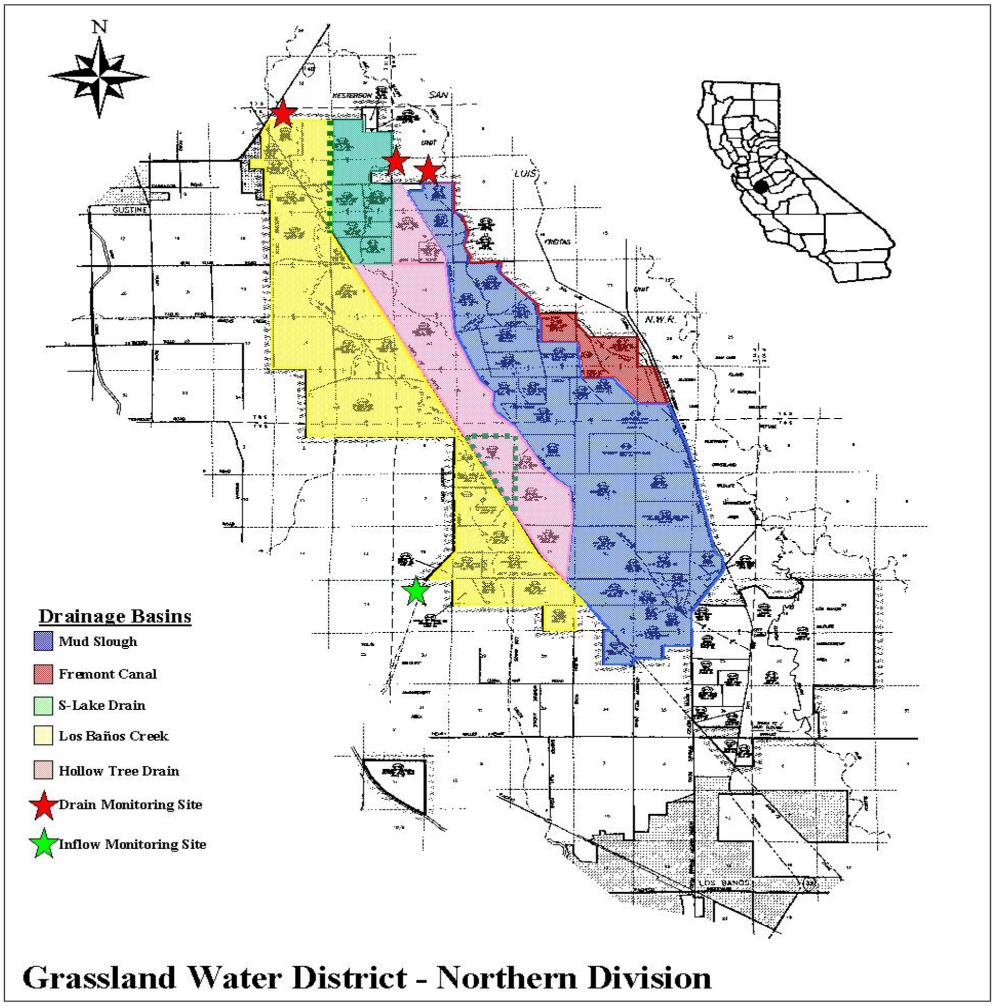

Figure 3. Wetland management areas within the North Grassland Water District (NGWD) showing location of real-time monitoring sites.

Changing the scheduling of wetland drainage to the San Joaquin River affects the timing and rate of drawdown of wetland ponds and hence the forage value of the wetlands for migrating and wintering shorebirds and waterfowl. Wetland salinity management measures can also affect the productivity and diversity of vegetation that can be grown in the watershed. A rapid waterfowl habitat assessment protocol, using a combination of remote sensing and wetland soil salinity mapping, is under development to assess changes in waterfowl habitat value over time.

Wetland habitat monitoring sites have been randomly chosen from available seasonal wetlands within the NGWD. These wetlands drain to locations where flow and EC monitoring sites are situated. At all wetland study plots, a paired study design is being used to directly assess differences in traditionally drained wetlands vs. non-traditionally drained wetlands. The habitat monitoring is being conducted on adjacent traditionally and non-traditionally drained wetlands. The monitoring includes both a waterbird (waterfowl and shorebirds) usage component and a moist-soil plant production component. The waterbird component measures abundance and diversity and determine time-activity budgets of waterbirds through scan sampling and direct observation to assess foraging potential. The moist-soil plant production component determines the impacts, if any, to the vegetation by assessing changes in total plant biomass, percent coverage, and species composition through grid sampling and aerial photography.

DECISION SUPPORT SYSTEM DESIGN

The rationale for developing a decision support system (DSS) was to provide a set of analytical tools that assist in computation of NGWD wetland water requirements, estimation of wetland salinity load in seasonal wetlands and in the selection of best management practices. A requirement of the DSS was that it be simple in design and intuitive, similar to data management tools typically used by the GWD. Further, the DSS was designed to interact with existing San Joaquin River water quality forecasting models and software to allow the partition of River assimilative capacity among the wetland releases.

WETLAND WATER QUALITY MODEL

The wetland water quality model (WWQM) simulates the seasonal wetland flooding regime in the NGWD and mimics the wet/dry seasonal cycle that these wetlands experience. As well, it has the ability to track the quantity and water quality of the wetland releases to the San Joaquin River. The main objective of the wetland water quality model is to predict the effects of salt loading to the San Joaquin River during spring drawdown (January-April). The model incorporates the daily water use requirements of the seasonal wetland habitat in the NGWD (and is currently being expanded to include the adjacent State and Federal refuges). Evapotranspiration from moist-soil plants within the NGWD is presently estimated and not specifically modeled owing to lack of field data for model calibration. There are no reliable techniques available using remote sensing technology to quantify the areal extent of the major moist-soil plants and other wetland habitat within the NGWD. In spite of these limitations the model tracks salinity changes in each of the wetlands over the winter season and incorporates user-defined schedules for wetland drawdown in the spring months. By running scenarios of different weekly wetland flood-up and drainage schedules and annual changes in vegetation type and waterbird usage, managers are able to plan operations to minimize water quality impacts on the San Joaquin River while maximizing wildlife benefits (Williams, 1996)..

The current model was developed using the Microsoft Excel platform because of the widespread familiarity with this product among wetland managers in the Grassland Basin. The model has been designed to perform historic hydrology simulations as well as seasonal alternatives (along with sensitivity analyses). Seasonal alternatives include different wetland drawdown protocols such as (a) early drawdown (critically dry to dry year), (b) traditional drawdown (dry to wet year), (c) late drawdown (wet year), and (d) preflushing. The WWQM has been designed to allow easy linkages to popular software packages such as ARCGIS. In addition, the Excel spreadsheet model has been designed to predict salt loading from the NGWD watershed and read salt assimilative capacity output directly from the Department of Water Resources' Delta Simulation Model II (DSM-2). First the wetland water quality model provides wetland outflow quantities and salt loads to DSM-2 at Mud and Salt Sloughs for use in its river forecasts and second, the WWQM uses San Joaquin River assimilative capacity forecasts provided by DSM-2 as input.

Input Data

Input data for the WWQM fall into four categories: static, annually constant, annually varying, and real-time. Static data, which do not vary with time, include soil properties, land classifications, acreages, drainage basin allocations, and precipitation and ET qualities. Annually constant data, which are static year to year but vary within the year, include crop coefficients (for ET subroutines), best management practices, and water table depth. Annually varying data include water year classification, wetland flood-up and irrigation schedules. Real-time data include supply water quantity and quality, drainage water quantity and quality, evapotranspiration, precipitation, air, water, and soil temperatures, and San Joaquin River assimilative capacity. Much of the static and annually constant data are assumptions since intensive monitoring in these wetlands only commenced in water year 2000.

MODEL DEVELOPMENT AND OPERATION

The WWQM performs salt and water balances in a structured format that makes it easily adaptable to other wetland complexes in the region. The model assumes that wetland water management decisions can be equated to a desired pond depth in each wetland unit and the this depth can be set as a target. Daily hydrologic and water quality inputs (salt loads) are additive to achieve the desired pond depth (precipitation, wetland inflow, groundwater) whereas daily hydrologic and water quality outputs (evapotranspiration, direct evaporation, operational spills and pond seepage) are subtractive. As water evaporates from open water or transpires from wetland vegetation the residual salts in each ponded area are concentrated.

Keeping track of the salt concentration in each wetland management unit as delineated in Figure 3 is the major purpose of the WWQM..

For the NGWD, the WWQM is continually updated with input data from real-time monitoring stations within the NGWD as well as online data from State and federal water agencies. Climatic data (evaporation, evapotranspiration, and precipitation) is provided by the California Irrigation Management Information System (CIMIS) web site (http://www.cimis.water.ca.gov/), operated by the California Department of Water Resources. Wetland inflow and desired pond depth are linked to management strategies, and are updated based upon best management practices for the type of wetland being modeled. Assumptions are made concerning wetland groundwater seepage and operational spills during wetland delivery for the individual wetland units owing to the dearth of available data.

Model calibration is an ongoing process involving the comparison of model simulations and field data collected by the real-time monitoring network. In Figure 4 a preliminary comparison is shown between model predicted and average flow-weighted water quality for all wetland drainage sites in the NGWD.

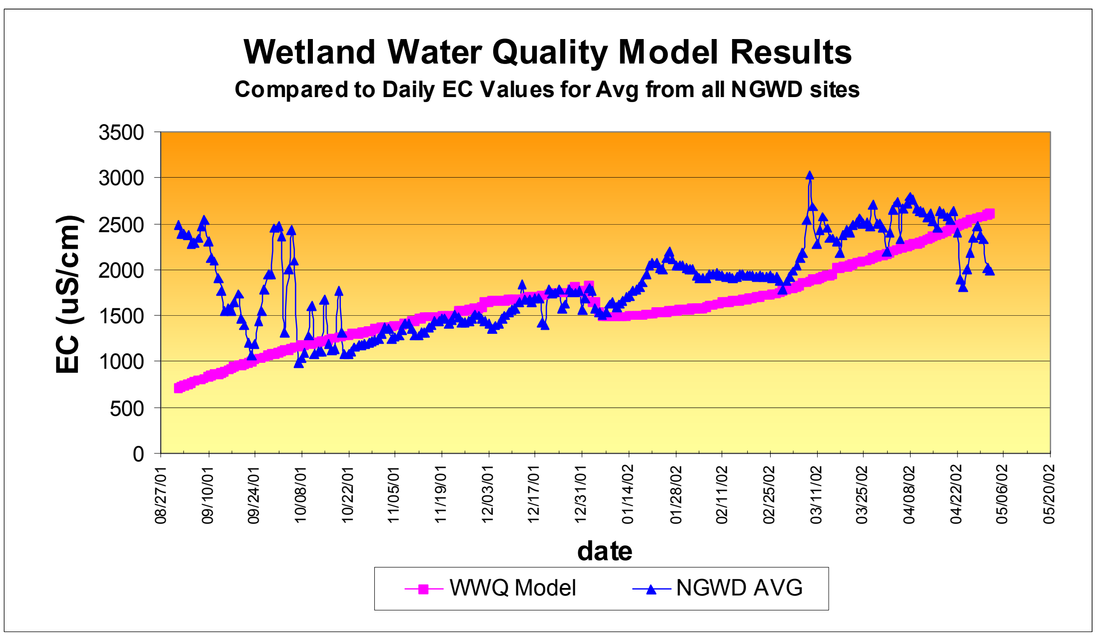

Figure 4. Comparison of model results and field observations of wetland drainage electrical conductivity.

ADAPTIVE MANAGEMENT OF WETLAND RELEASES

The synergy between the monitoring and research objectives of our project and the practical aspects of improving wetland function in a climate of increased environmental regulation and control of non-point source discharges provides a unique opportunity for advancement of the art and the science of wildfowl wetland management. Experiences documented and data gathered, following the manipulation of the timing of wetland flood-up and release during each year of the project, will be analyzed and evaluated to determine the impacts to habitat quality and suitability and to food availability. These impacts will be contrasted with the benefits to San Joaquin River water quality achieved through discharging drainage from seasonal wetlands during periods of assimilative capacity for salt and trace elements of concern such as boron and selenium.

SUMMARY

Successful implementation of the monitoring program and DSS described in this paper could provide the basis for adaptive management of wetland drainage throughout the entire 150,000 acre (68,000 hectare) Grassland Ecological Area. This will require the cooperation of local landowners, duck club operators, and managers of State and Federal refuges in the Grassland Basin. A significant remaining challenge will be to develop the regional entity envisaged by the CRWQCB that will take responsibility for making assimilative capacity allocation decisions for the watershed. Achieving this goal may require the CRWQCB to facilitate institution building by further disaggregating their salinity and boron TMDL load limits to create separate targets for agriculture and wetland entities discharging to the San Joaquin River.

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